CHRISTENSEN ASSOCIATES

Reply Comments of

Mark E. Meitzen, Ph.D. and Philip E. Schoech, Ph.D.

Christensen Associates
800 University Bay Dr Ste 400
Madison WI 53705-2299

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INTRODUCTION

We are Dr. Mark E. Meitzen and Dr. Philip E. Schoech of Christensen Associates. We previously submitted an assessment of the FCC's proposed options for the special access price cap X factor in which we concluded that the BLS KLEMS method, properly adjusted, is the best approach for establishing the X factor. We also concluded that among the different time periods under consideration for calibrating the X factor, the 2005-2013 period was the most appropriate. Over the 2005-2013 period the BLS KLEMS method produced an X factor of 1.95%.[1]

With these reply comments we provide information on updates that the BLS has made to its KLEMS database, and we calculate a revised X factor value using these updated data. We find that using the updated BLS KLEMS data, which now extend through 2014, an X factor based on the 2005-2014 period would be 1.99%.

We also comment on the declaration of David E.M. Sappington and William P. Zarakas submitted on behalf of Sprint Corporation on June 28, 2016.[2] In their declaration, Sappington and Zarakas support the use of a TFP-based methodology to compute a special access X factor, but reject the figures proposed by the Commission for a X factor or price reset under the BLS KLEMS methodology and the Commission's existing rules for price cap index construction. Rather, they assert that a different data source, time period and calculation methodology would yield superior results. In particular, they suggest that instead of using the KLEMS database for U.S. productivity developed by the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor, the Commission should rely on a database developed by a European research consortium known as EU KLEMS. As we describe below, the Sappington-Zarakas proposal is plagued by a fundamental misunderstanding of the EU KLEMS data, and is based on inappropriate methods for establishing the X factor. In addition, we point out why CACM-based data remain unsuitable for use in development of a TFP-based X and why these data provide no confirmation of Sappington and Zarakas' analysis.

UPDATE TO THE BLS KLEMS DATABASE

On June 22, 2016 the BLS updated its KLEMS database for nonmanufacturing industries.[3] Appendix 1 to these reply comments shows the updated data released by the BLS for "broadcasting and telecommunications" and our updated X factor calculations. Since the BLS revised some of its historical data in the update, the compound annual growth rates are slightly different than the growth rates we reported in our initial assessment. Table 1 provides an update of the X factor calculation for the year ranges 1997-2014, 1997-2003, 2005-2014; and for comparison purposes: 2005-2013.

[1] Mark E. Meitzen and Philip E. Schoech, "Assessment of the FCC's Proposed Options for the Special Access Price Cap Factor," June 28, 2016.
[2] Declaration of David E.M. Sappington and William P. Zarakas, "SZ Declaration," June 28, 2016.
[3] See note in the "For Your Information" section of the BLS multifactor productivity homepage, http://www.bls.gov/mfp/ (Visited July 13, 2016). The updated data are available at http://www.bls.gov/mfp/mprdload.htm.

Table 1
Updated X-Factor Based on KLEMS Data

Year Range	GDP-PI	Industry TFP	Industry Input Price	X-Factor Based on June 2016 Data	X-Factor Based on May 2016 Data
1997-2014	1.96%	1.88%	1.53%	2.31%	
1997-2003	1.77%	-0.08%	-0.34%	2.02%	2.02%
2005-2014	1.87%	1.60%	1.49%	1.99%	
2005-2013	1.90%	1.59%	1.49%	2.00%	1.95%

The updated BLS KLEMS data produce results that are very similar to what we initially reported. Using the most recent data available, the BLS KLEMS database supports an X factor of 1.99% based on the most recent ten years of data available (2005-2014). Given that the factor previously calculated based on May 2016 KLEMS data for the slightly shorter 2005-2013 period was 1.95%, this demonstrates the stability of the BLS KLEMS methods and provides additional support for using this method for setting the special access X factor.

CRITIQUE OF THE SAPPINGTON-ZARAKAS DECLARATION

Sappington and Zarakas argue that EU KLEMS provides a better database for determining a price cap X factor because, unlike the BLS KLEMS database used by the Commission in its analysis, EU KLEMS data do not commingle statistics from the telecommunications and broadcasting industries. Rather, they claim that these data are telecommunications-only.[4] They suggest that this telecommunications-only feature of the EU KLEMS data should override the fact that EU KLEMS data are not available for years after 2010, whereas BLS KLEMS data are now available through 2014. Based on a peculiar selection of data out of the EU KLEMS database, Sappington and Zarakas claim to calculate a 1998-2010 compound annual growth rate of 3.4% for telecommunications-only productivity and a compound annual growth rate of 0.8% for telecommunications input prices.[5]

In evaluating the Sappington and Zarakas declaration, we find that they fundamentally misinterpreted the EU KLEMS data on which they based their recommendation. First, contrary to Sappington and Zarakas' assertion, the EU KLEMS data definitions document clearly states that the data that EU KLEMS uses to represent the U.S. are sourced from the BLS and Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce and are not specific to telecommunications, but also include broadcasting. Second, the productivity measure Sappington and Zarakas extract from the EU KLEMS database is a "value added" productivity measure and not the "gross output" type of productivity measure that would be appropriate for setting a special access X factor pursuant to the Commission's price cap regulations. Third, the input price measure that Sappington and Zarakas use is not a comprehensive measure of industry input prices, as it leaves out the prices of capital and labor—the input factors that comprise the majority of the industry's costs. These problems, in addition to the fact that the EU KLEMS data include no years after 2010, make their recommended approach both faulty and undesirable.

[4] SZ Declaration, p. 8.
[5] SZ Declaration, p. 11.

Sappington and Zarakas also propose a less comprehensive method for calculating a special access X factor from the industry productivity and input price growth series they extract from the EU KLEMS database. Instead of using the historical rate of GDPPI growth to represent national productivity and input price growth, as employed by the Commission staff in the FNPRM and consistent with the mandate in the Commission's regulations for adjusting the price cap index by offsetting growth in GDPPI by the X factor, Sappington and Zarakas propose to substitute partial measures for these national economy trends. The partial measures they propose are BLS statistics for multifactor productivity and input price growth in just the private nonfarm business sector of the national economy. As we demonstrated in our initial assessment, in addition to being consistent with the mandate in the Commission's Part 61.45 rules to use GDPPI in the PCI formula, calibration of the X factor against GDPPI is theoretically rigorous and in accord with the literature on calibrating X factors. In addition to being unnecessarily complex, use of private nonfarm business sector data in setting the X factor is less desirable than GDPPI because it covers a more limited portion of the national economy than does GDPPI.

Finally, in addition to their proposal to use inapposite EU-KLEMS data coupled with measures of national productivity and input prices at odds with Commission requirements, Sappington and Zarakas indicate that CACM-based input price growth estimates suggested as an option in the FNPRM confirm that the partial input price growth series they employ in their proffered X factor calculations is reasonable.[6] Indeed, this correspondence suggests the exact opposite. Since Sappington and Zarakas' derivation of an input price growth series is incorrect, the fact that CACM-based input price growth estimates may suggest similar growth is only evidence that CACM-based input price growth estimates may also be faulty.

Sappington and Zarakas are Wrong in Asserting the EU KLEMS Data Are Specific to Telecommunications and Exclude Broadcasting

Sappington and Zarakas assert that the EU KLEMS data separate telecommunications from broadcasting while the BLS commingles those industries.[7] However, EU KLEMS sources its U.S. data from the BLS and BEA for developing its industry statistics for the United States.[8] Indeed the EU KLEMS' project's documentation of its data states explicitly that data it reports in its data tables for the U.S. under the row caption of "Telecommunications" (NACE 2 Sector 61) are comingled broadcasting and telecommunications data provided by the BLS/BEA for NAICS industries 515 and 517.[9] Since the sole reason given by Sappington and Zarakas for using EU KLEMS data instead of BLS KLEMS multifactor productivity data—their believed purity of the former's data—is incorrect, this is reason enough to

[6] SZ Declaration, pp. 19-20.
[7] SZ Declaration, p. 8 ("EU KLEMS data … are best suited to the task at hand because they remove the broadcasting component from the BEA/BLS data").
[8] *EU KLEMS Growth and Productivity Accounts 2012 release: Description of methodology and country notes for the United States*, Prepared by Reitze Gouma and Marcel Timmer (Groningen Growth and Development Centre) http://www.euklems.net/data/nace2/USA_sources_12i.pdf (visited July 1, 2016), page 1. The link to this document is in the same row on the same webpage (http://www.euklems.net/eukISIC4.shtml#top) as the link used to access the EU KLEMS data for the U.S.
[9] ibid., page 6.

disregard their further analyses.[10] Indeed, the EU KLEMS data are inferior to the BLS KLEMS data simply because the former are truncated at 2010, while the later continue through 2014.

EU KLEMS Develops a Value Added Productivity Measure which is Inappropriate for Special Access Price Cap Calibration

A second reason for rejecting the Sappington-Zarakas calculations of TFP from the EU KLEMS database is that the productivity measure that they select from this database is a "value added" rather than a "gross output" measure of productivity for broadcasting and telecommunications.[11] A value added productivity measure first develops constant dollar value added of an industry by subtracting its constant dollar intermediate inputs (energy, materials, and services) from its constant dollar total output. This index for the industry's value added is then compared to a quantity index of the industry's capital and labor inputs. In contrast, the BLS multifactor productivity index for broadcasting and telecommunications compares the quantity of this industry's gross output with a quantity index for its capital, labor, energy, materials, and services input quantities (i.e., the complete set of inputs employed to produce telecommunications outputs).

The theory underlying the calibration of a price cap productivity factor has been laid out in various academic articles.[12] The basic principle underlying price cap calibrations is that a cap on the price of a final output should mimic the pricing dynamics of a competitive industry supplying the same final output. In perfectly competitive industries there are no economic profits, and total revenues increase at only the same rate as total costs. If this holds, the price index of final outputs will increase at the same rate as the price index of all inputs, less the rate of total factor productivity growth – where total factor productivity is the ratio of total (gross) output to total input. Because the Commission's price cap plan for special access caps the total price of the final output (e.g., a DSn service), an appropriate productivity factor for this plan must be set with respect to both the TFP growth of final (i.e., gross) output and the complete collection of input prices paid (e.g., capital, labor, energy, materials and services) to produce this gross output. In particular, because the special access prices capped by the Commission's price cap plan are total prices, not just the value-added component of total prices, it is incorrect to measure telecommunications TFP with respect only to the industry's value-added component for the purposes of setting a price cap X factor.

[10] Indeed, because all EU KLEMS data used by Sappington and Zarakas do commingle telecommunications and broadcasting, the comments on p. 9 and footnote 17 of their declaration about how broadcasting productivity may have differed from telecommunications productivity are specious. In any event, as we noted in our initial declaration, broadcasting only comprises a small portion of the combined U.S. telecommunications and broadcasting industries: 18% by revenue and only 8% by property, plant and equipment. Thus, it is highly improbable that telecommunications-only statistics would differ significantly from those of the combined industry.

[11] The EU KLEMS project was initiated to assess differences across countries in the contribution of particular industries to national productivity growth. For this reason, to avoid double-counting the contribution of a particular industry (as both a producer of final products and as an input supplier to downstream industries) to national total factor productivity growth, EU KLEMS uses a "value added" approach to measuring the productivity of each industry. However as discussed below, this conceptual framework is inappropriate for calibrating a price cap X factor that caps the total price charged for a special access service.

[12] For example, see Laurits R. Christensen, Philip E. Schoech, and Mark E. Meitzen, "Telecommunications Productivity," in Gary Madden, ed. *Traditional Telecommunications Networks* (Edward Elgar, 2003), pp. 103-105.

A value added productivity measure will mathematically exceed the rate of gross output total factor productivity growth.[13] It is possible to demonstrate the extent of this overstatement using elements of the EU KLEMS database to construct a total factor productivity measure that compares the quantity of gross output to the combined quantities of capital, labor, energy, materials, and services. The data in Appendix 2 were taken directly from the EU KLEMS web site and represent the data underlying its "value added" productivity measure. The EU KLEMS database for the United States also includes a quantity measure of broadcasting and telecommunications "gross output" as well as measures of the costs associated with each of the five input categories (capital, labor, energy, materials, and services) necessary to produce gross output. This allows us to construct a Tornqvist quantity index for total input using methods similar to those used by BLS to construct its quantity indexes for total input used in the construction of its multifactor productivity indexes. Deriving total factor productivity by taking the ratio of the EU KLEMS gross output quantity measure to the quantity index of total input, we find that the gross output total factor productivity compound annual growth rate implicit in the EU KLEMS data is 1.8% over the 1998-2010 period, which is approximately half of the value added productivity compound annual growth rate of 3.4% adduced by Sappington and Zarakas.

Sappington and Zarakas Employ the Wrong Price Index in Determining the Rate of Industry Input Price Growth

To develop an X factor, Sappington and Zarakas net their measure of valued added TFP for broadcasting and telecommunications against an input price index that they report in Table 1 on page 10 of their declaration. Comparing this price index to the various input price data series contained in the EU KLEMS database confirms that they selected the series that EU KLEMS titles II_P, which EU KLEMS documentation defines as its price index for "intermediate inputs." But (as EU KLEMS documentation confirms) "intermediate Inputs" are only energy, materials, and services, and exclude the primary inputs of capital and labor.[14] As a result, the index employed by Sappington and Zarakas to adjust for input price changes to the telecommunications industry does not include the prices of capital or labor, two components that by themselves constitute over half of the total input cost incurred in producing telecommunications services.

[13] The fact that value added productivity growth overstates the rate of total factor productivity growth, where total factor productivity is the ratio of gross output to total input, is well documented in the productivity literature. See Erwin Diewert, "Reconciling Gross Output TFP Growth with Value Added TFP Growth," *International Productivity Monitor*, No. 29, Fall 2015, pp. 60-67 (available at http://www.csls.ca/ipm/29/diewert.pdf). Also see *OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth* (OECD, 2001), p. 26 (available at http://www.oecd-ilibrary.org/industry-and-services/measuring-productivity-oecd-manual_9789264194519-en) and Paul Schreyer, "The OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity, "*International Productivity Monitor*, No. 2, Spring 2001, pp. 37-51 (available at http://www.csls.ca/ipm/2/schreyer-e.pdf).

[14] These documents provide detailed definitions of the content of EU KLEMS' II_P variable: "EU KLEMS Growth and Productivity Accounts, Version 1.0," pp. 6-8 (available at http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_I_Methodology.pdf) and "An Overview of the EU KLEMS Growth and Productivity Accounts," p. 8 and footnote 9 (available at http://ec.europa.eu/economy_finance/publications/publication9467_en.pdf).

The Use of Private Nonfarm Business Sector Multifactor Productivity and Private Nonfarm Business Sector Price of Total Input is Inappropriate

The Commission's X factor is intended to account for the productivity growth net of input price performance in the telecommunications industry relative to the productivity growth net of input price performance in the national economy. The X factor equation given in paragraph 405 in the main text of the FNPRM and in paragraph 3 of its Appendix C demonstrates that since the inception of price caps in CC Docket No. 87-313, the Commission has used GDPPI (or its predecessor GNPPI) to represent national productivity and input price growth trends. Rather than accepting this precedent, Sappington and Zarakas propose using TFP and input price growth measured in just the private nonfarm business sector of the national economy to represent national trends. While doing this is not completely inadmissible, we showed in our initial assessment that GDPPI growth is equal to the difference between economy-wide total input price growth and economy-wide total factor productivity growth, thus one can calibrate the X factor using just GDPPI instead of employing separate series for input price and total factor productivity growth in the national economy. Because GDPPI comprehensively amalgamates national productivity and input price growth, there is no need to separately determine economy-wide total input price growth and economy-wide total factor productivity growth in the X factor calibration.

More concerning is that the more complex method proposed by Sappington-Zarakas to combine these two "national" measures employs indexes for productivity and input price growth that derive only from the private nonfarm business portion of the national economy. These measures thus exclude the farm sector as well as the government and not-for-profit sectors of the economy, which are included in the scope of the GDPPI.[15]

In any event, if it is determined (as Sappington and Zarakas advocate) that national productivity and input price trends should be modeled by just the private nonfarm business sector of the economy and not by GDPPI, this will result is a smaller X factor. The reason is simple. Productivity growth relative to input price growth has been stronger in the private nonfarm business sector of the national economy than in its government, farm, and nonprofit sectors. Over the 2005-2014 period, TFP growth in the private nonfarm business sector has been 0.42% annually. This sector's input price growth has been 2.02%. Combining these figures with BLS KLEMS Telecommunications plus Broadcasting TFP of 1.60% and input price growth of 1.49% over this same period yields an X factor of 1.72%. This is in comparison to the X factor of 1.99% we derived when national productivity and input price trends are modeled by GDPPI growth.[16]

[15] The private nonfarm business sector excludes that portion of Gross Domestic Product that is produced by the government sector, the nonprofit sector, and the farm sector. In 2014, these excluded sectors accounted for 27% of gross domestic product. (Gross domestic product was $17.3 trillion while the current dollar output of the private nonfarm business sector was $12.7 trillion.) The figure for gross domestic product comes from the BEA National Income and Product Account Table 1.1.5 (available at http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1#reqid=9&step=3&isuri=1&903=5). The figure for the private nonfarm business sector comes from the multifactor productivity workbook on the BLS website (available at http://www.bls.gov/mfp/special_requests/prod3.mfptable.zip).

[16] We note that neither Sprint nor Sappington and Zarakas advocate the addition of a consumer productivity dividend to calculated X factors. As we noted in our initial declaration, there is no basis for such an additive unless the proposed change in regulation is expected to goad greater productivity. This is not the case here.

Combining KLEMS data with Input Price Indexes Developed for CACM is Inappropriate

Sappington and Zarakas indicate that CACM-based input price growth estimates suggested as an option in the FNPRM confirm that the EU KLEMS telecommunications input price growth estimates they employ in their proffered X factor calculation are reasonable. This conclusion is faulty for a number of reasons, the first of which is that Sappington and Zarakas misinterpret the EU KLEMS input price series they are using. Rather than being an index of all input prices, this series encompasses only intermediate inputs and not capital and labor. As a result, any concordance of CACM-based input price growth to EU KLEMS intermediate input-based price growth only suggests that both are wrong for this application. In addition, the CACM-based input prices are constructed in a manner inconsistent with the methods used to construct input prices for use in KLEMS TFP measures. Moreover, as we noted in our initial assessment, the input price measures developed for CACM are highly unlikely to reflect the actual technologies being used to provide BDS.

KLEMS TFP prices for capital inputs are for the annual user or rental price for capital services. This is a function of: the initial purchase price of capital goods; economic depreciation of these capital goods resulting from the aging of assets and declines in their technological efficiency; and changes in interest rates and other costs of capital.[17] The CACM-based figures appear simply to be estimates of the changes in initial purchase prices for various pieces of new capital equipment. The CACM-based capital price series were not produced using the rigorous methods for calculating the user cost of capital services—which are required by both BLS and EU KLEMS TFP analyses. Thus, there is no basis to use them in a TFP-based development of X. Given that the input price measures offered by TDS suffer from the same infirmities, they are also inappropriate for use in a TFP-based development of the X factor.

In addition to the mismatch with KLEMS TFP data requirements, the input prices developed for use with CACM are estimates derived from numerous idiosyncratic sources and, thus, have an indeterminate relationship to input prices of the actual technologies used to provide BDS. It is also unclear from the FCC's description how a time series for these prices was established back to 1997 and how these proxy prices may relate to a time series of actual prices over this time period.[18] The only explanation appears in the FNPRM's Appendix C stating that for each of the four listed year ranges (i.e., 1997-2015, 1997-2013, 1997-2003, and 2005-2013), "two weighted averages were computed for changes in input prices: one high and one low."[19] We believe there is little likelihood that these input prices derived from CACM reflect the prices of the actual technologies that provide BDS:

> In our view, this process provides little comfort or assurance that these hypothesized input price series, or their growth, bear any relationship to actual input prices, particularly for the legacy networks that provide the

[17] See Paul Schreyer, "The OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity, "*International Productivity Monitor*, No. 2, Spring 2001, pp. 37-51 (available at http://www.csls.ca/ipm/2/schreyer-e.pdf). Also see the *BLS Handbook of Methods*, Chapter 11 (available at http://www.bls.gov/opub/hom/pdf/homch11.pdf); and "Technical Information about the BLS Multifactor Productivity Measures" (available at http://www.bls.gov/mfp/mprtech.pdf).

[18] Mark E. Meitzen and Philip E. Schoech, "Assessment of the FCC's Proposed Options for the Special Access Price Cap Factor," June 28, 2016, p. 12.

[19] Federal Communications Commission, Tariff Investigation Order and Further Notice of Proposed Rulemaking, WC Docket Nos. 16-143, 15-247, 05-25 and RM-10593, Appendix C, para 12.

> majority of BDS; if anything, it indicates that another level of unverifiable estimates are layered on top of the hypothetical proxy model input prices this approach begins with.[20]

There is even less reason for an X factor analysis to consider CACM-based input price trends because the FNPRM proposes to combine these input prices with a national TFP measure developed by a researcher at the San Francisco Federal Reserve Bank. Given that this TFP measure is not even specific to the telecommunications industry, the proposed methodologies that use this TFP measure and CACM-based input prices are clearly inferior to the direct use of BLS KLEMS information.

CONCLUSION

As we stated in our initial assessment of the FNPRM's proposed methods for setting the special access X factor, the BLS KLEMS methodology provides by far the best approach. The BLS recently released an update to its KLEMS data, which allows us to add information for 2014 to the analysis. Including the year 2014 to the post-2005 period, yields an X factor of 1.99%, which is very consistent with previous studies of the industry. Moreover, given that regulated BDS are largely provided by obsolete legacy technologies whose capacity utilization is declining, it is likely that calculated industry-wide TFP growth represents an upper bound for the TFP growth actually realized by these particular services.

Dr. Sappington and Mr. Zarakas offer an ill-considered alternative to the three options proposed in the FNPRM. Specifically, they propose to rely on EU KLEMS data. But contrary to statements made in their declaration, the EU KLEMS data are not specific to the U.S. telecommunications industry as they also include broadcasting. Further, the TFP measure they extract from EU KLEMS is a value added TFP measure, and not a measure of gross output TFP that is needed if the purpose is to develop an X factor to cap the total price of BDS. Moreover, the input price index they extract from EU KLEMS is one that measures only growth in prices for intermediate inputs and excludes price growth for capital and labor inputs. Rather than calibrating these industry measures against comprehensive national measures for TFP net of input price growth represented by GDPPI, they propose to restrict national measurements to the private nonfarm business sector. Finally, the EU KLEMS data are stale, as they end in 2010. This is in contrast to BLS KLEMS data that extend through 2014. For all of these reasons, the FCC should not consider the approaches recommended by Sappington and Zarakas and should use BLS KLEMS data for setting the X factor.

Proposals have also been made to use CACM-related data on input price trends to develop an X factor. As noted above, CACM-based estimates of input usages have little correspondence to the input usages actually deployed and the associated price estimates for these inputs do not provide a reliable or accurate measure of input prices that are consistent with a TFP-based development of X. Thus, such proposals should be rejected. BLS KLEMS provides the most valid approach to determining the X factor.

[20] Mark E. Meitzen and Philip E. Schoech, "Assessment of the FCC's Proposed Options for the Special Access Price Cap Factor," June 28, 2016, p. 12.

APPENDIX 1: UPDATE OF THE BLS KLEMS CALIBRATION OF THE X FACTOR

On June 22, 2016, the BLS updated its KLEMS database for nonmanufacturing industries to include data for 2014.[21] Tables A1.1 and A1.2 at the back of this appendix show the updated data for the broadcasting and telecommunications industry.[22] The last column of A1.1 shows the BLS-calculated multifactor productivity index, which represents total factor productivity trends. The last column of A1.2 shows the BLS-calculated price index for combined inputs, which represents the input price trends.[23] The compound annual growth rate between year t and year t+n is derived from the formula:

$$\left(\frac{x_{t+n}}{x_t}\right)^{(1/n)} - 1$$

We calculate the compound annual growth rate for three year-ranges: 1997-2014, 1997-2003, and 2005-2014. These correspond to the year-ranges presented in the NPRM, but updated to include data now available for 2014. For comparison purposes, we also provide growth rates for the 2005-2013 period.

Calculation of the Industry TFP Compound Annual Growth Rate

The compound annual growth rates are computed as follows:

1997-2014:

$$\left(\frac{104.073}{75.844}\right)^{1/17} - 1 = 1.88\%$$

1997-2003:

$$\left(\frac{75.482}{75.844}\right)^{1/6} - 1 = -0.08\%$$

2005-2014:

$$\left(\frac{104.073}{90.216}\right)^{1/9} - 1 = 1.60\%$$

2005-2013:

$$\left(\frac{102.323}{90.216}\right)^{1/8} - 1 = 1.59\%$$

[21] These updates also included some minor revisions in earlier years due to revisions in the source data, in particular data that are obtained from the Bureau of Economic Analysis.

[22] See, "Nonmanufacturing Sectors and NIPA–level Nonmanufacturing Industries KLEMS Multifactor Productivity Tables by Industry." Available at http://www.bls.gov/mfp/special_requests/klemsmfpxg.zip.

[23] The BLS creates these indexes from their components using the Tornqvist method. See Michael J. Harper, et. al., "Nonmanufacturing industry contributions to multifactor productivity, 1987-2006," *Monthly Labor Review*, June 2010, pp. 16-31. Available at http://www.bls.gov/opub/mlr/2010/06/art2full.pdf.

Calculation of the Industry Combined Input Price Compound Annual Growth Rate

The compound annual growth rates are computed as follows:

1997-2014:

$$\left(\frac{104.008}{80.312}\right)^{1/17} - 1 = 1.53\%$$

1997-2003:

$$\left(\frac{78.702}{80.312}\right)^{1/6} - 1 = -0.34\%$$

2005-2014:

$$\left(\frac{104.008}{91.072}\right)^{1/9} - 1 = 1.49\%$$

2005-2013:

$$\left(\frac{102.520}{91.072}\right)^{1/8} - 1 = 1.49\%$$

Calibrating these elements against GDPPI compound annual growth rates as specified by the equation stated in paragraph 405 of the FNPRM text and in paragraph 3 of its Appendix C produces the following X factor results.

Year Range	GDP-PI	Industry TFP	Industry Input Price	X-Factor Based on June 2016 Data	X-Factor Based on May 2016 Data
1997-2014	1.96%	1.88%	1.53%	2.31%	
1997-2003	1.77%	-0.08%	-0.34%	2.02%	2.02%
2005-2014	1.87%	1.60%	1.49%	1.99%	
2005-2013	1.90%	1.59%	1.49%	2.00%	1.95%

Table A1.1

BLS Output, Input and Multifactor Productivity Indexes

Table Multifactor Productivity and Related KLEMS Measures from the NIPA Industry Database, 1987 to 2014

Broadcasting and telecommunications (NAICS 515, 517)

1 Real Sectoral Output, Input Quantities, and Multifactor Productivity

2 Indexes = 100.000

Base Year = 2009

Year	Sectoral Output	Capital Services	Labor Input	Capital Intensity	Intermediate Inputs	Energy	Materials	Purchased Services	Combined Inputs	Multifactor Productivity
1987	28.256	28.789	88.810	30.300	29.689	N.A.	N.A.	N.A.	38.972	72.503
1988	30.757	30.298	89.760	31.633	31.307	N.A.	N.A.	N.A.	40.613	75.731
1989	31.711	31.748	90.852	32.734	30.012	N.A.	N.A.	N.A.	41.108	77.143
1990	32.628	33.356	90.424	34.540	28.717	N.A.	N.A.	N.A.	41.535	78.555
1991	32.887	34.798	88.678	36.791	28.079	N.A.	N.A.	N.A.	41.949	78.397
1992	34.398	36.575	89.388	39.076	28.213	N.A.	N.A.	N.A.	43.140	79.736
1993	36.393	38.398	90.764	40.411	28.886	N.A.	N.A.	N.A.	44.649	81.508
1994	39.260	40.396	93.570	41.687	30.777	N.A.	N.A.	N.A.	46.896	83.717
1995	42.218	42.712	98.646	42.256	38.633	N.A.	N.A.	N.A.	51.904	81.339
1996	46.941	45.470	101.567	43.559	46.572	N.A.	N.A.	N.A.	56.934	82.449
1997	50.312	48.884	106.123	44.383	63.813	107.795	26.667	75.156	66.336	75.844
1998	55.478	53.107	113.078	45.629	73.628	133.006	30.367	86.784	73.541	75.438
1999	62.438	59.290	118.851	47.932	89.697	209.093	42.820	102.846	84.108	74.236
2000	68.613	68.660	126.920	52.069	101.051	281.929	52.572	113.701	94.306	72.756
2001	69.354	78.417	124.877	59.480	102.171	334.234	50.271	115.391	97.918	70.828
2002	69.519	82.741	116.588	68.762	100.870	242.949	48.999	115.187	96.927	71.723
2003	71.600	82.763	110.377	72.833	99.302	186.290	55.358	111.695	94.857	75.482
2004	76.628	83.332	110.245	75.180	95.741	135.426	62.613	105.268	93.551	81.911
2005	84.026	85.139	107.396	78.719	94.365	116.766	68.215	101.925	93.139	90.216
2006	90.720	88.170	107.177	81.513	99.914	99.786	80.679	105.643	96.526	93.985
2007	95.801	91.996	105.524	85.997	97.275	99.181	89.711	99.427	96.794	98.974
2008	99.780	96.563	103.992	92.065	96.616	103.122	91.844	97.873	98.184	101.626
2009	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
2010	105.055	102.730	97.100	107.712	111.806	97.836	130.924	106.787	104.951	100.100
2011	110.228	105.583	94.171	113.930	126.346	101.050	165.138	116.260	111.068	99.244
2012	114.610	108.554	93.446	121.642	135.559	113.718	186.682	122.240	115.660	99.092
2013	117.022	111.546	92.833	125.970	129.761	97.647	182.967	116.134	114.365	102.323
2014	124.236	114.367	92.922	128.769	139.844	104.713	198.228	124.918	119.374	104.073

Source: Bureau of Labor Statistics June 22, 2016

Office of Productivity and Technology

Division of Major Sector Productivity

Table A1.2
BLS Output and Input Indexes

Table Multifactor Productivity and Related KLEMS Measures from the NIPA Industry Database, 1987
Broadcasting and telecommunications (NAICS 515, 517)
2 Output and Input Prices
2 Indexes = 100.000
Base Year = 2009

Year	Price of Sectoral Output	Price of Capital Services	Price of Labor	Price of Intermediate Inputs	Price of Energy	Price of Materials	Price of Purchased Services	Price of Combined Inputs
1987	94.931	106.451	34.547	69.411	N.A.	N.A.	N.A.	68.828
1988	94.244	108.777	36.229	72.867	N.A.	N.A.	N.A.	71.372
1989	95.711	115.313	35.898	75.266	N.A.	N.A.	N.A.	73.834
1990	97.461	118.370	38.228	77.563	N.A.	N.A.	N.A.	76.560
1991	98.753	117.298	39.344	80.095	N.A.	N.A.	N.A.	77.419
1992	99.238	120.528	39.787	81.833	N.A.	N.A.	N.A.	79.128
1993	100.354	125.004	41.713	82.940	N.A.	N.A.	N.A.	81.796
1994	101.072	128.030	44.559	84.940	N.A.	N.A.	N.A.	84.615
1995	103.670	124.088	46.217	85.982	N.A.	N.A.	N.A.	84.324
1996	104.448	126.630	47.765	87.119	N.A.	N.A.	N.A.	86.116
1997	105.891	105.376	48.997	87.515	65.722	130.035	81.835	80.312
1998	105.519	101.238	51.149	86.725	64.455	122.383	81.748	79.602
1999	104.294	85.344	57.646	86.940	64.461	115.557	82.723	77.424
2000	104.732	77.008	60.492	87.477	68.078	110.059	83.895	76.199
2001	103.746	61.337	67.026	87.507	71.644	103.193	84.649	73.481
2002	103.826	59.482	73.432	86.963	71.439	101.777	84.205	74.467
2003	104.266	67.070	77.705	88.279	75.930	100.423	85.761	78.702
2004	103.957	82.288	79.867	89.858	79.409	100.870	87.461	85.152
2005	100.949	96.490	78.643	93.020	87.323	102.034	90.869	91.072
2006	99.866	99.550	79.499	96.790	94.472	104.588	94.809	93.859
2007	101.016	108.265	91.494	96.646	98.466	103.015	94.946	99.980
2008	101.413	113.160	92.639	99.150	108.651	102.485	98.113	103.062
2009	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
2010	99.558	99.037	98.057	101.156	105.292	98.694	101.859	99.658
2011	99.226	92.966	100.947	102.415	112.776	97.629	103.897	98.476
2012	99.906	93.035	101.071	103.490	109.688	95.337	106.396	98.998
2013	100.192	100.783	103.242	103.992	111.143	93.348	107.955	102.520
2014	99.937	102.184	104.750	105.550	117.128	92.597	110.465	104.008

Source: Bureau of Labor Statistics June 22, 2016
Office of Productivity and Technology
Division of Major Sector Productivity

APPENDIX 2: ANALYSIS OF THE EU KLEMS DATA

As noted above, the analysis of EU KLEMS data performed by Sappington and Zarakas inappropriately extracts and employs a value-added measure of industry productivity that ignores the vast contributions of purchased inputs to the production and sale of special access telecommunications services. Further, the input price index extracted and employed by Sappington and Zarakas from EU KLEMS was simply one for intermediate inputs and excluded any changes in prices for the primary capital and labor inputs used to produce telecommunications services. Based on these two inapposite data series, Sappington and Zarakas compute a 1998-2010 figure of 3.4% for growth in telecommunications value-added TFP, and a figure of 0.8% for growth in input prices, which because of the series they examined, consisted only of intermediate inputs and excluded capital and labor inputs. The purpose of this appendix is to reanalyze the EU KLEMS data to develop a gross-output TFP measure and to compare this measure to the inapposite value-added measure developed by Sappington and Zarakas.

The tables at the end of this appendix were downloaded from the EU KLEMS database on July 13, 2016.[24] Table A2.1 shows the descriptions of the different variables contained in that database. Table A2.2 shows the data contained in the rows of this EU KLEMS database that are captioned as "Telecommunications," (but noted as EU sector 61 which EU KLEMS corresponds to NAICS 515 and 517). The Sappington-Zarakas productivity index, given on page 10 of their declaration displays the values given for variable TFPva_I in Table A2.2—a variable that EU KLEMS describes as "TFP (value added based) growth, 2005 = 100." The Sappington-Zarakas input price index on page 10 of their declaration corresponds to the variable II_P, which EU KLEMS defines as the price index for "Intermediate inputs, price indices, 2005 = 100." This intermediate inputs price index includes as its components price indices for energy, materials, and services, but excludes indices for the prices of capital and labor.[25]

To construct gross output total factor productivity index from EU KLEMS data, we need to compute the ratio of gross output to the complete input combination consisting of capital, labor, energy, materials, and services. To do this, we extract the following variables from the EU KLEMS database:

- Gross output quantity: GO_QI
- Capital quantity: CAP_QI
- Labor quantity: LAB_QI
- Energy quantity: IIE_QI
- Materials quantity: IIM_QI
- Services quantity: IIS_QI

To compute the Tornqvist quantity index of these five inputs we use their respective costs:

- Capital compensation: CAP
- Labor compensation: LAB

[24] http://www.euklems.net/euklSIC4.shtml/USA_output12i.xlsx.

[25] See the following documents that provide detailed definitions of the content of EU KLEMS' II_P variable: "EU KLEMS Growth and Productivity Accounts, Version 1.0," pp. 6-8 (available at http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_I_Methodology.pdf) and "An Overview of the EU KLEMS Growth and Productivity Accounts," p. 8 and footnote 9 (available at http://ec.europa.eu/economy_finance/publications/publication9467_en.pdf).

- Intermediate energy inputs at current purchasers' prices: IIE
- Intermediate materials inputs at current purchasers' prices: IIM
- Intermediate services inputs at current purchasers' prices: IIS

The Tornqvist quantity index of total input is constructed by the formula:

$$\ln\left({X_t}/{X_{t-1}}\right) = \sum_{i=K,L,E,M,S} .5 \cdot \left(s_{it} + s_{i,t-1}\right) \cdot ln\left({x_{it}}/{x_{i,t-1}}\right)$$

$$s_{it} = \frac{cost_{it}}{\sum_{j=K,L,E,M,S} cost_{jt}}$$

where X is the quantity index of total input, x_{it} represents the quantity index of input i in year t, and $cost_{it}$ represents the cost of input i in year t. We use the Tornqvist index formula to compute year to year changes in the index, base the index to 100 in 2005, and recursively compute the values for other years from this base year value. Dividing the quantity index for gross output by the quantity index for total input yields the proper gross output total factor productivity index. This is shown in the following table.

Quantity Indexes of Gross Output, Total Input and Total Factor Productivity Constructed from the EU KLEMS Database

Year	Gross Output	Total Input	Total Factor Productivity
1998	66.687	76.907	86.711
1999	75.585	87.610	86.274
2000	84.466	97.592	86.550
2001	87.769	102.788	85.388
2002	88.750	102.846	86.294
2003	89.193	101.522	87.856
2004	92.801	100.143	92.669
2005	100.000	100.000	100.000
2006	104.424	102.607	101.771
2007	108.263	102.529	105.593
2008	112.060	103.549	108.219
2009	110.384	104.463	105.668
2010	113.625	105.727	107.470
Compound Average Growth Rate			**1.80%**

As can be seen (and to be expected by economic theory), this gross-output TFP of 1.80% over the 1998-2010 period is much less than the inapposite value-added measure of 3.4% computed by Sappington and Zarakas for the same period.

Table A2.1

Information Retrieved from the EU KLEMS Database

USA Basic Tables	
Source: EUKLEMS database, March 2013 release	
Variables	
Values	
GO	Gross output at current basic prices (in millions of US Dollars)
II	Intermediate inputs at current purchasers' prices (in millions of US Dollars)
IIE	Intermediate energy inputs at current purchasers' prices (in millions of US Dollars)
IIM	Intermediate material inputs at current purchasers' prices (in millions of US Dollars)
IIS	Intermediate service inputs at current purchasers' prices (in millions of US Dollars)
VA	Gross value added at current basic prices (in millions of US Dollars)
Prices	
GO_P	Gross output, price indices, 2005 = 100
II_P	Intermediate inputs, price indices, 2005 = 100
IIE_P	Intermediate energy inputs, price indices, 2005 = 100
IIM_P	Intermediate material inputs, price indices, 2005 = 100
IIS_P	Intermediate service inputs, price indices, 2005 = 100
VA_P	Gross value added, price indices, 2005 = 100
Volumes	
GO_QI	Gross output, volume indices, 2005 = 100
II_QI	Intermediate inputs, volume indices, 2005 = 100
IIE_QI	Intermediate energy inputs, volume indices, 2005 = 100
IIM_QI	Intermediate material inputs, volume indices, 2005 = 100
IIS_QI	Intermediate service inputs, volume indices, 2005 = 100
VA_QI	Gross value added, volume indices, 2005 = 100
H_EMP_QI	Hours worked, volume indices, 2005 = 100
LP_I	Gross value added per hour worked, volume indices, 2005 = 100
Growth accounting	
LAB	Labour compensation (in millions of US Dollars)
CAP	Capital compensation (in millions of US Dollars)
LAB_QI	Labour services, volume indices, 2005 = 100
CAP_QI	Capital services, volume indices, 2005 = 100
VA_Q	Growth rate of value added volume (% per year)
VAConH	Contribution of hours worked to value added growth (percentage points)
VAConLC	Contribution of labour composition change to value added growth (percentage points)
VAConK	Contribution of capital services to value added growth (percentage points)
VAConTFP	Contribution of TFP to value added growth (percentage points)
TFPva_I	TFP (value added based) growth, 2005 = 100

Table A2.2

Information Retrieved from the EU KLEMS Database

Variable	desc	code	_1998	_1999	_2000	_2001	_2002	_2003	_2004	_2005	_2006	_2007	_2008	_2009	_2010
GO	Telecommunications	61	413,281	460,190	505,564	519,621	519,640	523,817	541,695	570,373	592,351	618,382	636,687	625,715	644,811
VA	Telecommunications	61	220,698	233,918	256,823	267,286	267,916	268,259	288,188	310,692	315,510	345,537	357,191	338,936	347,282
II	Telecommunications	61	192,584	226,272	248,742	252,334	251,724	255,557	253,507	259,682	276,841	272,844	279,497	286,779	297,528
GO_QI	Telecommunications	61	66.7	75.6	84.5	87.8	88.8	89.2	92.8	100.0	104.4	108.3	112.1	110.4	113.6
VA_QI	Telecommunications	61	59.1	64.6	73.4	78.0	79.6	80.0	87.6	100.0	104.6	113.8	121.0	115.4	119.3
II_QI	Telecommunications	61	76.3	89.9	98.7	100.3	100.4	100.8	99.3	100.0	104.3	101.9	102.0	104.5	107.1
GO_P	Telecommunications	61	108.7	106.7	104.9	103.8	102.7	103.0	102.3	100.0	99.5	100.1	99.6	99.4	99.5
VA_P	Telecommunications	61	120.2	116.5	112.6	110.3	108.3	107.9	105.9	100.0	97.1	97.7	95.0	94.5	93.7
II_P	Telecommunications	61	97.2	96.9	97.1	96.9	96.6	97.6	98.3	100.0	102.2	103.1	105.6	105.7	107.0
IIE	Telecommunications	61	1,948	3,132	4,838	5,996	4,537	5,538	6,074	6,765	6,417	5,431	6,420	5,196	5,217
IIM	Telecommunications	61	26,840	32,919	32,938	28,147	25,062	25,231	26,755	27,359	31,925	32,321	33,451	31,203	38,147
IIS	Telecommunications	61	163,796	190,221	210,966	218,191	222,125	224,788	220,678	225,558	238,499	235,092	239,626	250,380	254,164
IIE_QI	Telecommunications	61	59.0	90.0	114.6	134.0	110.1	110.5	106.5	100.0	87.7	70.9	71.7	75.5	66.9
IIM_QI	Telecommunications	61	79.7	102.7	106.9	97.1	88.5	92.1	98.7	100.0	114.8	117.6	121.2	115.6	141.9
IIS_QI	Telecommunications	61	76.0	87.9	97.1	99.9	101.6	101.7	99.1	100.0	103.5	101.0	100.6	104.1	104.3
IIE_P	Telecommunications	61	48.8	51.4	62.4	66.2	60.9	74.1	84.3	100.0	108.2	113.3	132.3	101.8	115.3
IIM_P	Telecommunications	61	123.0	117.2	112.6	106.0	103.5	100.2	99.1	100.0	101.6	100.4	100.8	98.7	98.3
IIS_P	Telecommunications	61	95.5	95.9	96.3	96.8	96.9	98.0	98.7	100.0	102.2	103.2	105.6	106.7	108.0
LP_I	Telecommunications	61	53.6	55.0	59.5	62.1	69.5	74.7	84.9	100.0	106.1	117.4	127.8	129.0	141.1
CAP	Telecommunications	61	133,988	135,843	149,450	159,965	163,789	162,799	180,309	204,252	206,778	226,888	238,878	225,560	237,667
LAB	Telecommunications	61	86,710	98,075	107,373	107,321	104,127	105,460	107,879	106,440	108,732	118,649	118,313	113,376	109,615
CAP_QI	Telecommunications	61	61.8	70.1	82.6	95.2	100.5	99.6	99.1	100.0	102.2	105.7	110.1	113.3	115.9
LAB_QI	Telecommunications	61	108.1	114.9	122.4	123.0	113.4	106.5	104.3	100.0	99.4	98.0	95.2	88.9	85.1
H_EMP_QI	Telecommunications	61	110.2	117.6	123.5	125.5	114.5	107.1	103.2	100.0	98.6	96.9	94.7	89.5	84.5
VA_Q	Telecommunications	61	0.26	8.94	12.82	5.98	2.08	0.52	9.04	13.25	4.46	8.51	6.13	-4.75	3.30
TFPva_I	Telecommunications	61	76.4	75.7	76.1	74.2	75.7	78.4	86.8	100.0	103.3	110.5	115.5	110.6	114.1
VAConTFP	Telecommunications	61		-0.97	0.63	-2.65	2.05	3.49	10.22	14.14	3.26	6.76	4.39	-4.33	3.13
VAConK	Telecommunications	61		7.44	9.52	8.43	3.23	-0.51	-0.36	0.61	1.40	2.23	2.73	1.87	1.56
VAConH	Telecommunications	61		2.64	2.06	0.66	-3.62	-2.61	-1.42	-1.13	-0.50	-0.57	-0.78	-1.91	-1.84
VAConLC	Telecommunications	61		-0.17	0.60	-0.47	0.43	0.16	0.60	-0.37	0.30	0.09	-0.22	-0.38	0.45